THE MULTIPLE THREATS OF GLOBAL WARMING, METHANE RELEASE, AND OCEAN ACIDIFICATION

by C.A. Tolman 3/26/06

Fifty five million years ago the earth experienced the most rapid and extreme global warming event in its geologic history, called the Paleocene-Eocene Thermal Maximum (PETM). This massive extinction event was accompanied by increases in sea-surface temperatures (SST) of 5°C in the tropics and as much as 9°C in the Arctic, with bottom water warming 4-5°; the initial SST warming took only about 1000 years.[i] A change in the C^{13}/C^{12} isotope ratio of sea sediments suggests that the heating was due to an increase in the greenhouse effect brought about by a sudden release into the atmosphere of about 2000 Gt of carbon in the form of methane. (A Gt (gigaton) is a billion metric tons.) The methane was oxidized to CO_2, enough of which dissolved in the ocean to make it sufficiently acidic to dissolve the calcium carbonate all the way to the sea floor, changing the color of the normally white sediment to the dark color of clay—presumably killing corals, shellfish, and most of the calcareous (calcium carbonate-containing) plankton at the base of the oceanic food chain. Recovery took over 100,000 years.

Large quantities of methane (CH_4) (estimates are said to be 1000-22,000 Gt, with most about 10,000 Gt) occur in the ocean at relatively low temperatures and high pressures (deeper than 500 meters) in the form of methane hydrate—a type of ice containing about 13% methane by weight. It is stable under current conditions of temperature and pressure, but could melt, releasing the methane, if the temperature on the sea floor rises 2-3°C.[ii] Once the release started, the warming would cause further release, creating a positive feedback that could run away, no matter what people tried to do at that stage. Thus global warming as a result of burning fossil fuels has the potential to destabilize the methane hydrates, release massive amounts of methane into the atmosphere, and duplicate or exceed the large temperature increases and ocean acidification of the PETM.

A recent paper by David Archer at the University of Chicago reports computer modeling studies on the atmosphere/ocean/sea-floor system in which CO_2 pulses of various sizes (300, 1000, 2000 and 5000 Gt C) were released into the atmosphere, followed by equilibration of CO_2 between the air and ocean, increasing ocean temperatures, dissolving $CaCO_3$ in the ocean, and silicate rock weathering on land.[iii] (Weathering of silicate rock adds calcium to the ocean and gradually removes carbon by sedimentation of $CaCO_3$.) Archer was interested in seeing how long the CO_2 would remain in the atmosphere, once added. Possible sources include burning of fossil fuels (current reserves are estimated to be about 5000 Gt, 90% of which is coal), the terrestrial biosphere (mostly trees, about 500 Gt), soil organic carbon (about 1,500 Gt), and methane hydrate (5,000-10,000 Gt on the seafloor. For comparison, human activities—mostly burning fossil fuels and deforestation—have added about 300 Gt to the atmosphere since the beginning of the Industrial Revolution. A business-as-usual scenario, in which carbon emissions increase by 1.3% per year, would add 1300 more Gt C by the end of this century, with the anthropogenic emission rate increasing from the current 7 Gt/yr to 24 Gt/yr in 2100. At that rate we would reach a total of 2000 added Gt in 2115. Archer's model indicates that adding 2000 Gt of C as CO_2 would increase the atmospheric CO_2 from the current 380 ppm to over 800 ppm, increase the mean ocean temperature by 2.3°C—perhaps enough to begin releasing methane from its hydrate—and increase ocean acidity enough to cause net dissolution of $CaCO_3$. In other words, continuing to burn fossil fuels until we've used about 40% of the known reserves is a recipe for repeating or exceeding (especially if there are now 10,000 Gt C in the hydrate) the disastrous climate changes of the PETM; whether any humans would survive is uncertain.

---

[i] James C. Zachos et al., **Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum**, *Science*, **308**, pp. 1611-1615 (2005).
[ii] Barbara Maynard, **Burning Questions about Gas Hydrates**, *Chemistry*, pp. 27-33 (Winter 2006).
[iii] David Archer, **Fate of fossil fuel CO2 in geologic time**, *Journal of Geophysical Research*, **110**, C09S05 (2005).